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Counting or measuring the stomata *in situ* on the leaf is possible with a few plants, notably *Begonia coccinea*, *Chrysanthemum frutescens*, *Fuchsia speciosa*, *Impatiens Sultani*, *Primula obconica*, *Pelargonium zonale*, *Tradescantia zebrina*, and *Vicia Faba*. In some others the condition of the pore can thus be observed, though the outlines of the guard cells are not clear; this is true in *Senecio Petasitis*, *Helianthus annuus*, *Cyclamen latifolium*, *Coleus Blumei*, *Cestrum elegans*, and *Phaseolus vulgaris*.

Marked variations in number and size of stomata occur, not only in different varieties of the same species, but in the same varieties grown under different external conditions. So far as my observation goes, however, the variation is greater in number than in size. Furthermore, while in most leaves the stomata are fairly evenly distributed over the surfaces containing them, in some, especially in oblong leaves (e. g., *Fuchsia speciosa*, *Helianthus annuus*, and *Impatiens Sultani*), the stomata are much more numerous near the base than near the tip (more than twice as many), and near the midrib than near the margin. For this reason very different figures might be given for the same leaf by different observers.

The opening and closing of the stomata of greenhouse plants is correlated closely with the time of day, and secondarily with the weather. As already noted, they are, as a rule, as wide open as they can be about 10 A. M.—this, of course, in well-watered plants. In favorable weather they remain wide open until about 2.30 P. M., when they begin to close, and they are mostly completely closed by 5 P. M., though some may remain open until 6. On hot days in the spring they may close as early as 12 M., probably because of incipient wilting of the leaf. If the stomata are closed by wilting, they may be made to open, partially at least, by immersion of the leaf in water.

The best plants for general laboratory study, taking account of ease of removing the epidermis, size and clearness of stomata, and commonness of occurrence in greenhouses, are, in order of excellence, *Chrysanthemum frutescens*, *Tradescantia zebrina*, *Pelargonium zonale*, *Fuchsia speciosa*, *Helianthus annuus*, and *Vicia Faba*.—SOPHIA H. ECKERSON, *Smith College, Northampton, Mass.*

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## THE ABSORPTIVE POWER OF A CULTIVATED SOIL

(WITH THREE FIGURES)

In the winter of 1908 we undertook a study of the absorptive power of a certain soil from one of the fields of the Michigan Agricultural College. In addition to the purely analytical methods which have been exclusively employed up to the present time in investigations of this kind, it was decided

to approach the problem in a somewhat different way. If the absorptive power of the soil is a factor of real importance, so far as plant life is concerned, it would be reasonable to expect that a concentration of a given salt solution which has proved to be detrimental for a given kind of plant when grown in soil extract would be beneficial or at least do no harm to the same kind of plant when grown in the soil itself.

With this idea in mind, we undertook (1) to determine the maximum tolerance of wheat seedlings to concentrations of certain salts when grown in soil extract to which known quantities of the salt in question were added; (2) to grow the same kind of plants in paraffined wire baskets,<sup>1</sup> using the

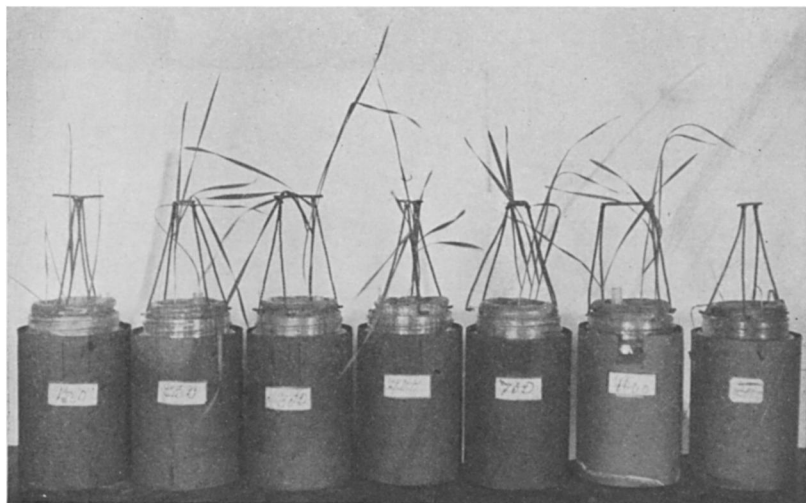


FIG. 1.—Tolerance of wheat seedlings to solutions of  $\text{Na}_2\text{HPO}_4$ ; roots immersed in the solution: 1, distilled water; 2, soil extract (2:1); 3, extract + 300ppm  $\text{P}_2\text{O}_5$ ; 4, same + 500ppm; 5, same + 700ppm; 6, same + 1000ppm; 7, same + 2000ppm.

same kind of soil, making it up to the proper moisture content, and watering the plants with solutions of the same salts, of concentrations equal to and higher than the maximum tolerance determined for the extract by cultures.

$\text{Na}_2\text{HPO}_4$ , KCl, and  $\text{NaNO}_3$  were selected for use, separately and in various combinations. Some of the results obtained with the phosphate salt are given here. The extract was prepared by mixing a known quantity of air-dry soil with twice its weight of distilled water, leaving the mixture, with occasional stirring, for 48 hours, and filtering off the liquid. Portions

<sup>1</sup> The method devised by the Bureau of Soils, U. S. Dept. Agric. (see Bull. 23 and others of the Bureau).

of this extract were then made up to contain 300, 500, 700, 1000, and 2000 parts per million of  $P_2O_5$  in the form of  $Na_2HPO_4$ .

The plants were set in small wire baskets (paraffined along the sides only) containing some sterile quartz sand, and the baskets placed in jars containing the proper extract, as shown in *figs. 1* and *2*. One set of plants was prepared with the roots immersed in the liquid, another with roots remaining in the sand. The cultures were aerated by pouring the liquid from one jar into another and the losses by evaporation and transpiration were made up daily with the corresponding extracts. The effect is seen

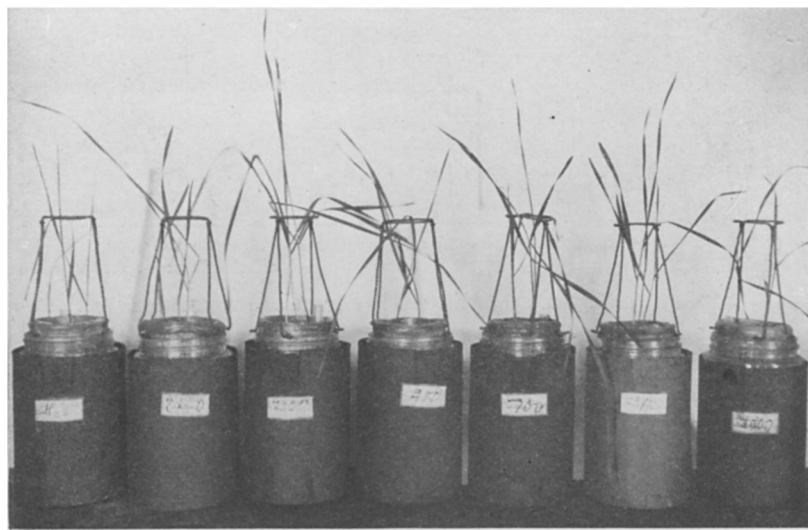


FIG. 2.—Tolerance of wheat seedlings to solutions of  $Na_2HPO_4$  in soil extract; roots kept in sand of the baskets: 1, distilled water; 2, soil extract (2 water: 1 soil); 3, extract + 100<sup>ppm</sup>  $P_2O_5$ ; 4, same + 500<sup>ppm</sup>; 5, same + 700<sup>ppm</sup>; 6, same + 1000<sup>ppm</sup>; 7, same + 2000<sup>ppm</sup>.

from the photographs. Up to the 700<sup>ppm</sup><sup>2</sup> concentration there was no marked difference between the two lots of plants. But while 700<sup>ppm</sup> immersed plants had a decidedly sickly appearance, the non-immersed ones looked quite healthy even in the 1000<sup>ppm</sup> extract. The 2000<sup>ppm</sup> of the non-immersed lot kept on struggling along even after three weeks from planting; while the immersed ones were killed in less than ten days.

It is thus seen that even the sterile quartz enables the plants to resist higher concentrations of the phosphates. The actual amount of salt

<sup>2</sup> Parts per million.

absorbed by the quartz was found to be about 10 per cent. in ppm of the original quantity. It was determined in the following way. The basket with the sand was removed from the jar. A sample was immediately taken to determine the water content; at the same time another portion of the same sand was washed with distilled water in ten successive portions. The washings were then evaporated to the volume calculated from the results obtained with the first sample (per centage of moisture in the sand) and the phosphates in the liquid determined. The phosphates in the extract contained in the jar from which the basket was removed were also determined,



FIG. 3.—Wheat seedlings in unmanured soil: upper row, left to right, all watered for last 7 days with  $P_2O_5$  solution (1, 10,000ppm; 2, 7,000ppm; 3, 6,000ppm); middle row, left to right, watered in same way (1, 5,000ppm; 2, 4,000ppm; 3, 3,000ppm); lower row, left to right, watered during all 29 days (1, 2,000ppm; 2, 1,000ppm; 3, distilled water).

and the difference between these determinations taken as the amount of phosphates absorbed by the sand.

The tolerance of the wheat seedlings to concentrations of the phosphate was very much increased when grown in the soil proper, as shown in *fig. 3*. Even concentrations of 6,000ppm, as seen also from the columns of "green" and "air-dry" weights in Table A, had no injurious effect on the plants. Only a concentration of 10,000ppm was distinctly harmful.

The addition to the soil of unsterilized, fairly well-rotted cow manure,

in the ratio of 1:250, enabled the plants to resist still higher concentrations, as seen from the same table.

TABLE A  
COMPARATIVE RESULTS AT THE END OF 30 DAYS

TREATMENT		SOIL NOT MANURED				MANURE NOT STERILIZED			
		No. of basket	Transpiration	Green weight	Air-dry weight	No. of basket	Transpiration	Green weight	Air-dry weight
During the entire 30 days	Dist. $\text{H}_2\text{O}$ . . . . .	27	224	3.00	0.41	16	220	3.5	0.48
	1000 <sup>ppm</sup> $\text{Na}_2\text{HPO}_4$	9	152	3.05	0.45	6	160	3.8	0.50
	2000 " "	12	146	3.00	0.48	18	143	4.0	0.60
During the last 7 days	*3000 " "	10	122	3.20	0.54	13	138	3.55	0.56
	4000 " "	11	135	3.10	0.42	17	143	3.5	0.58
	5000 " "	8	186	3.10	0.42	5	180	3.5	0.55
	6000 " "	7	178	3.20	0.41	4	187	3.8	0.58
	7000 " "	26	190	2.90	0.38	15	195	3.7	0.54
	10000 " "	25	180	2.20	0.34	14	184	3.5	0.52

\* Up to the last 7 days the even numbers of the following set were watered with a 2000<sup>ppm</sup> and the odd ones with a 1000<sup>ppm</sup> solution.

That the increased tolerance of the wheat seedlings to the concentration of the salt is actually due, at least to a very great extent, to the absorptive power of the soil is sustained by the following facts:

(1) The analytical studies show that the soil actually removes large quantities of the phosphoric acid from the solution, as seen by the following table:

TABLE B  
ABSORPTION OF PHOSPHATE BY THE SOIL

P.P.M. OF $\text{P}_2\text{O}_5$ IN ORIGINAL SOLUTION	METHOD	SOIL NOT MANURED		SOIL MANURED	
		Ppm. $\text{P}_2\text{O}_5$ in filtrate or percolate	Per cent. of $\text{P}_2\text{O}_5$ in Ppm. absorbed	Ppm. $\text{P}_2\text{O}_5$ in filtrate or percolate	Per cent. of $\text{P}_2\text{O}_5$ in Ppm. absorbed
1000	A*	795	20.5	745	25.5
1000	B†	728	27.2	698	30.2
2000	A*	1740	26.0	1700	30.0
2000	B†	1690	31.0	1674	32.6

\* METHOD A.—25<sup>gm</sup> of the soil mixed with 50<sup>cc</sup> of the corresponding solution left with occasional shaking for 48 hours, filtered and the filtrate analyzed for phosphates.

† METHOD B.—200<sup>gm</sup> of the soil placed in a wire basket (paraffined along the sides only) and 400<sup>cc</sup> of the corresponding solution allowed to percolate through the soil; the percolate analyzed for phosphates.

(2) In the case of a nitrate salt, where the absorption is a negligible quantity, the tolerance of the immersed and non-immersed plants, as will

be more fully demonstrated in a later communication, is practically the same.

(3) The tolerance increases with the increase of the absorptive power; both factors being lower in the quartz, higher in the unmanured soil, and still higher in the manured soil.—JOSEPH ROSEN and CHARLES HELLER, *Agricultural College, Michigan*.